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THE AIR LIFT[1]

By Arthur H. Ford[2]

Since the cost of pumping is one of the principal items in the cost of supplying water to the residents of a municipality, every water works manager is interested in discussions regarding the relative costs of pumping by different methods. Of late years, the air lift, as a means for raising water from deep wells, has become of such great importance that the writer deems a short discussion of the subject worthy of your attention.

Though air lifts have been used for the past fifty years for pumping water from wells of all depths, the theory of their operation has defied mathematical analysis; with the result that their design is almost wholly dependent on the use of empirical formulae. This has led to the improper design and operation of many lifts, to the detriment of their efficiency.

In general, an air lift consists of a water pipe extending a considerable distance below the water level in the well, where it is joined to an air pipe by means of a foot piece. The air pipe is connected to a compressed air receiver which is supplied with air by a compressor. It is thus seen that there are no moving parts in the well, which makes this type of pump especially desirable for use in crooked or deep wells, where the cost of repairs on pump rods and cylinders is large. The lack of moving parts in the well also increases the reliability, which is a great advantage in those cases where one well only is depended on for the water supply; it also makes it possible to handle water containing so much grit that reciprocating pumps will not answer, because of the excessive wear of the cylinders. Air lifts can pump water faster than any other type of pump, and are therefore frequently used for the purpose of testing new wells. The rapid rate of pumping water is such a desirable feature that this alone may lead to the use of an air lift in preference to a pump of some other form.

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[1] Read at the first annual meeting Iowa Section, American Water Works Association, at Iowa City, December 3, 1915.

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A picture of a working model of the simplest form of air lift is shown in figure 1. The outer tube (*W*) represents the well; connected to the catchment basin (*B*) by means of the siphon (*S*) which

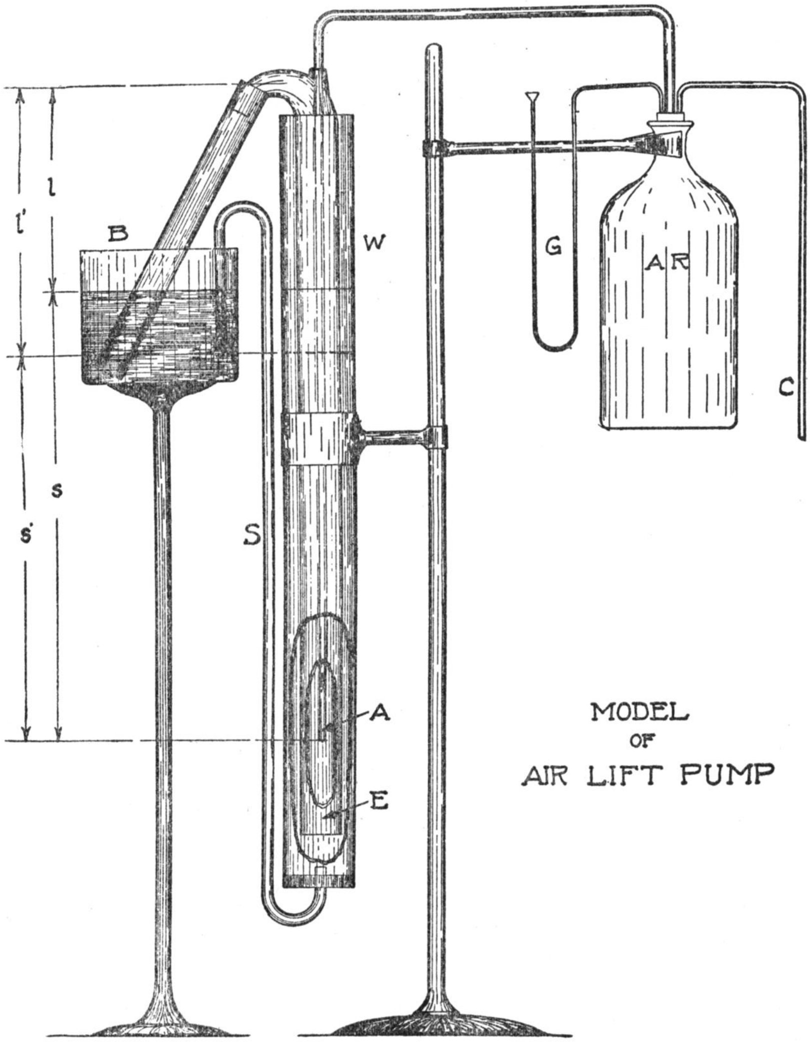

Fig. 1

represents the water passages in the rock. Inside the well is suspended the eduction tube (*E*) having the air tube (*A*) suspended in it, but not reaching quite to its bottom. The air tube is connected to the air receiver (*AR*) which is supplied with a pressure gauge (*G*) and a connection (*C*) to the air compressor (not shown).

When the compressor is started, the pressure in the air receiver gradually increases and the water is forced out of the air pipe until it is entirely empty, at which time the air pressure is at a maximum. The air now bubbles out of the end of the air pipe into the eduction pipe, which causes the level of the water in this pipe to rise an amount proportional to the volume of the air in the bubbles. As long as this does not bring the top of the column of air and water above the discharge opening in the eduction pipe, no water will be pumped and the air will merely bubble through the column of water. This condition obtains when the quantity of air supplied is insufficient to operate the lift.

The supply of a larger quantity of air will cause a larger proportion of the mixture in the eduction pipe to consist of air, with the result that the column will be higher, and when the air supply is sufficient the top will be above the discharge opening and the pump will begin to operate. The manner of operation will depend on the relation of the rate at which air is supplied to the area of the eduction pipe. When the rate of air flow is small, the air bubbles will be small in comparison with the size of the eduction pipe and the flow will be steady. Such a flow can be attained only when the pumping head (l) is small in comparison with the submergence (s) of the air pipe.

When the rate of air supply is increased, the size of the air bubbles increases until they entirely fill the eduction pipe and form air pistons enclosing slugs of water between them. The flow now becomes pulsating; discharges of water and air alternating. Every time that a slug of water is thrown out, the pressure at the lower end of the air pipe is slightly reduced and a quantity of air is emitted. This lifts the column of air and water in the eduction pipe, and at the same time stops the flow of water into the lower end; with the result that the level of the water in the well rises, increasing the water pressure at the end of the air pipe. As soon as the water pressure exceeds the air pressure the air flow stops until the pressure is again reduced by a slug of water being thrown out of the eduction pipe.

The maximum air pressure required to start a lift operating is equal to 2.31 times the submergence (s) of the air pipe, in feet. As soon as the lift begins to operate, the pressure is reduced, because of the drawing down of the water in the well, thus reducing the submergence to s', and increasing the head to l'. (See fig. 1.) This lowering of the water level may be considerable and is the determining factor in fixing the economical rate of pumping.

A number of the factors which enter into the efficiency of an air lift must of necessity be determined by experiment on the particular well in question; but some of them admit of generally applicable determinations being made. Among these is the best form of foot piece, as the connection between the air pipe and the eduction pipe is called. There are a number of forms of foot pieces on the market, for some of which extravagant claims of efficiency are made; but as wide variations in the efficiency are due to slight changes in the proportions of other parts of the system or the method of operation, such claims are to be looked on askance, unless they are backed up by adequate guarantees. Tests have shown that the effect of a change in foot piece may be to increase the efficiency as much as 50 per cent, when the head is high, with a much smaller increase when the head is low.[3]

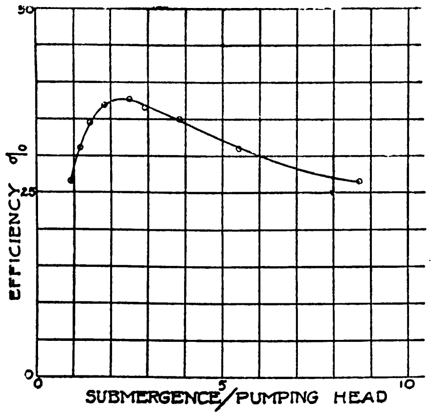

FIG. 2

The efficiency of even a well designed air lift is low; varying from 20 per cent for a lift of 600 feet, to 45 per cent for a lift of 50 feet; and is greatly influenced by the ratio of the submergence of the air pipe to the lift; the best ratio being about 2. This is clearly shown by a test of a well at Hattiesburg, Mississippi.[4] In this test, the speed of the air compressor was adjusted so as to keep the rate

[3] *Pumping by Compressed Air.* E. M. Ivens, page 146.

[4] Ibid., page 112.

of flow of water constant, while the length of the air pipe was varied. The data are given in the following table and shown in figure 2.

Total depth of well	453.5 feet
Inside diameter of casing	9⅝ inches
Inside diameter of air pipe	2½ inches
Inside diameter of eduction pipe	9⅝ inches
Static lift (l)	4.0 feet

Effect of submergence on efficiency pumping head

SUBMERGENCE	EFFICIENCY	SUBMERGENCE	EFFICIENCY
	per cent		*per cent*
8.70	26.5	1.86	36.8
5.46	31.0	1.45	34.5
3.86	35.0	1.19	31.0
2.91	36.6	0.96	26.5
2.25	37.7		

Flow about 1100 gallons per minute; pumping head about 37 feet.

These results show that the maximum efficiency is secured when the submergence is 2.5 times the lift, and that the efficiency falls off more rapidly for a reduction in the submergence than for an increase. It is a good plan therefore to have the submergence more than that calculated for the best efficiency rather than less. This allows for the usual occurrence, viz., that the pumping lift increases as more wells are sunk or during a dry season. Previous to this test the length of the air pipe in this well had been varied with a view to finding out the best flow at which to operate the well. The important data are given below and plotted in figure 3.

LENGTH OF AIR PIPE	FLOW	PUMPING HEAD	EFFICIENCY	DUTY
feet	*gal. per min.*	*feet*	*per cent*	*gal. per hp. hr.*
224	1495	47.5	32.6	1630
208	1459	45.8	31.5	1640
184	1419	44.3	31.1	1670
162	1359	39.4	30.0	1790
142	1299	37.7	30.6	1920
124	1219	37.5	32.8	2070
105	1106	37.1	36.7	2340
86	1008	32.5	33.4	2450
79	904	29.3	31.3	2530
67	802	26.0	30.5	2750
43	690	21.2	29.8	3240

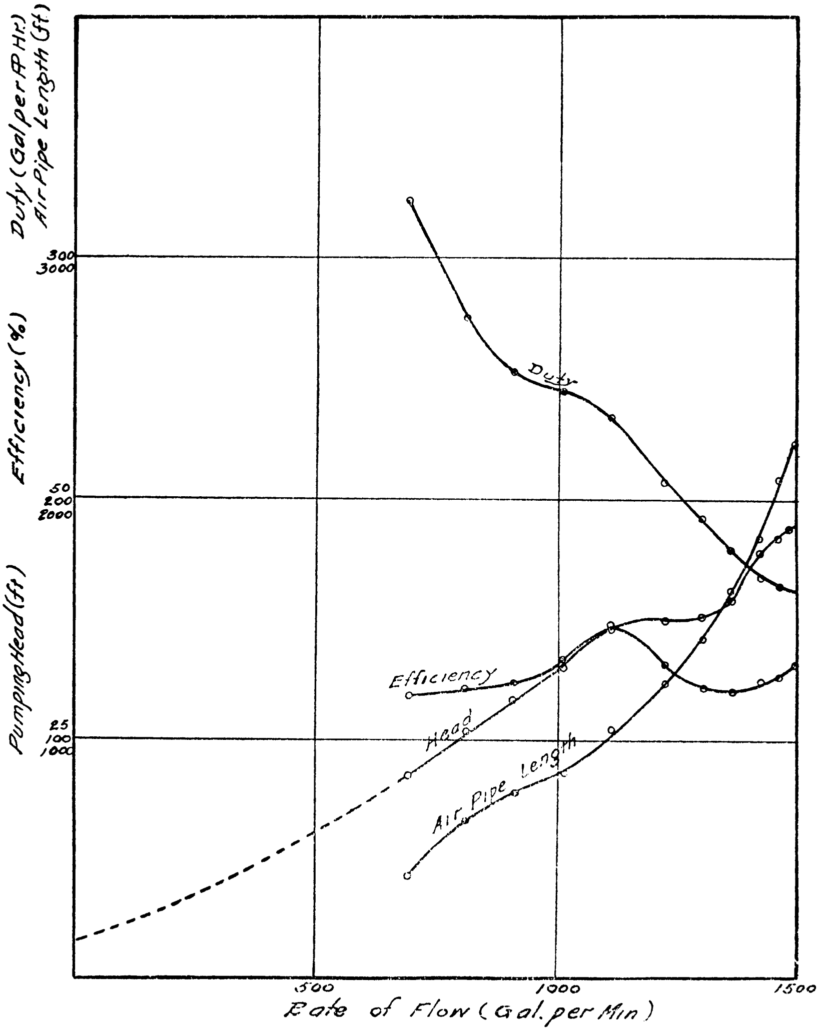
Duty (Gal per HP Hr.)
Air Pipe Length (ft.)
300
3000
Efficiency (%)
50
200
2000
Pumping Head (ft.)
25
100
1000
500
1000
1500
Rate of Flow (Gal. per Min)
Duty
Efficiency
Head
Air Pipe Length

FIG. 3

The air supply was apparently adjusted so as to get the best efficiency for each submergence.

This test shows an anomalous variation of the relation of pumping head to rate of flow; which is probably due to the coming into action of a second water bearing stratum, there being two cut by the well, when the level of the water had dropped 33 feet on account of the operation of the lift.

The writer believes that pump duty, water pumped per unit of energy supply, should be made the criterion of operation rather than mechanical efficiency. He has therefore calculated the last column.

This shows that the duty of the lift increases as the rate of pumping is decreased; which is due primarily to the decrease in the pumping head. The variation will be small for a free flowing well or one in which the drop due to pumping is small in comparison with the pumping head. This dictates that the well should be pumped at the minimum rate at which the desired quantity of water will be furnished.

When the well under discussion is operated at a flow of 1106 gallons per minute, at which flow the maximum efficiency was obtained, the pump duty was 2340 gallons per horse power hour; while if the pumping rate had been reduced to 690 gallons per minute the duty would have been 3240 gallons per horse power hour—an increase of 38 per cent. This would reduce the pumping expense 28 per cent.

The present status of the air lift is such that it can be considered as a thoroughly reliable piece of apparatus; but one should not be installed without the advice of an engineer who has made a special study of the subject, and he should be given opportunity to make trials with various lengths of air pipe and various speeds of compressor operation, after the lift has been installed; so as to find the conditions for best operation.